Predation as a Factor in Seasonal Abundance of *Musca sorbens* Wiedemann (Diptera: Muscidae)

GARY M. TOYAMA AND JAMES K. IKEDA
VECTOR CONTROL BRANCH
HAWAII STATE DEPARTMENT OF HEALTH
HONOLULU, HAWAII

Seasonal fluctuations in abundance of *Musca sorbens* Wiedemann were observed on a dairy at Kawailoa, Oahu. Fluctuation in fly populations, which increased during May-October and decreased during November-April, appeared to coincide with the two seasons (summer and winter) of Hawaii (Atlas of Hawaii, 1973). Our examination of factors that could cause this seasonal fluctuation suggested a relationship between environmental changes in cow dung pats and biological control agents. This study was initiated to: (1) demonstrate the existence of seasonal fluctuation; and (2) determine the cause for this seasonal variation in populations of *M. sorbens.*

MATERIALS AND METHODS

Three adjoining 5-acre corrals containing 20-30 dry, gestating cows per corral were used as the study site. These were the only uncrowded corrals at the dairy where untrampled fresh dung pats were available for *M. sorbens* breeding.

SEASONAL FLY ABUNDANCE

The following methods of monitoring fly density were used to demonstrate seasonal fly abundance: (1) trapping adult flies; (2) sampling dung pat infestation rates; and (3) sampling fly populations in dung pats.

Fly Trapping: Flies were trapped for 5 minutes with an inverted screen cone trap baited with fresh cow dung. Trapping was done bi-weekly for 11 months and then weekly for the remaining 14 months in the same corral.

Dung Pat Infestation Rates: Dung pats were inspected to determine percentages of pats infested with egg clusters and larvae. Successive pats encountered while randomly walking through the corral were examined until 40 pats were sampled (20 fresh pats for eggs and 20, 1-3 day-old pats for larvae). Sampling was done weekly for 15 months between 1000-2000 hours in the same corral.

Dung Pat Fly Populations: Fresh dung pats no longer attractive for oviposition were collected to determine the larval population in each dung pat. Monthly samples of 4 such dung pats were taken for 13 months from the same corral.

BIOLOGICAL CONTROL AGENTS

Seasonal difference in the effectiveness of biological agents in suppressing *M. sorbens* populations was determined by: (1) identifying all predators of *M. sorbens* at the dairy; (2) observing differences in summer and winter predation rates upon *M. sorbens* at the dairy; and (3) observing differences in summer and winter parasitization rates on *M. sorbens* puparia.

Predators: The predator population present at the dairy was ascertained through field observations and trapping with pitfall traps baited with fresh cow dung.

Predation Rates: Dung pats found in a corral were marked and left exposed to predators for varying periods of time. Exposure periods ranged from no-exposure, 24 hour exposure, and exposure until larvae had developed into the 3rd instar. Exposure time for 3rd instar larvae varied from 3 days in summer to 5 days in winter because of the difference in media tempurature. Winter (March-April) and summer (June-July) samples were collected between 1300-1400 hours.

Parasitization Rates: The population of parasites present at the dairy and their rate of parasitization of *M. sorbens* puparia were determined by placing dung pats containing 3rd instar larvae into shallow wooden boxes and exposing them to parasites in the corrals. Puparia were recovered after 4 days of exposure.

Dung Pat Environment

Effects of seasonal changes in sunlight intensity on the dung pat environment was studied by (1) measuring differences in dung pat and ambient tempuratures; (2) observing effects of meteorological factors on dung pats; and (3) determining whether the thick crusts forming on dung pats from increased summer solar radiation created a barrier between predator and prey.

Dung Pat Temperatures: Temperatures 12 mm below the surface of the dung pats were taken between 1100-1200 hours for 14 months.

Meteorological Effects on Dung Pats: Dung pats were examined weekly for 14 months to observe any changes in physical characteristics.

Dung Pat Crusts and Predation: During the summer season, crusts on fresh dung pats were softened with water between 1400-1500 hours to enable burrowing by nocturnal predators. Moistened and unmoistened test pats were marked and left exposed in the corral for 24 hours. Control pats were moistened before removal for laboratory rearing of flies. Sampling was done only on days with sunny mornings and overcast late afternoons to prevent rehardening of the moistened crusts before nightfall.

Results

Seasonal Fly Abundance

All data on seasonal abundance of *M. sorbens* showed similar summer peaks (fig. 1,2,3). Analysis of variance performed on the data showed significant differences occurring between summer (May-October) and winter (November-April) fly infestations.

Fly Trapping.—Fly density was significantly higher in summer than winter (Fig. 1: $F_{1,63} = 21.236$, $P < 0.001$).

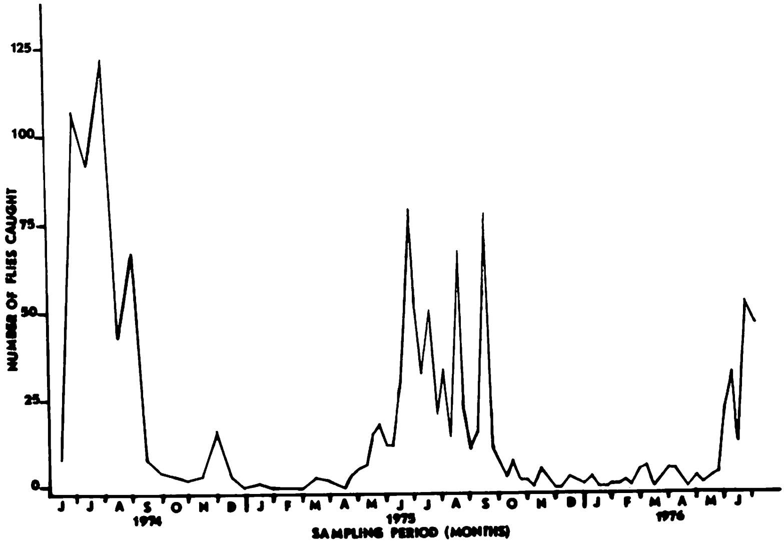

FIGURE 1. Seasonal variations in abundance of adult *M. sorbens* at the dairy. Five minute trapping with cone trap and fresh cow dung.

Dung Pat Infestation Rate.—Significantly more pats with egg clusters were observed in summer than in winter (Fig. 2: $F_{1,56} = 11.162$, $P < 0.001$). Similarly, significantly higher numbers of dung pats with larvae were observed in summer than winter (Fig.2: $F_{1,56} = 30.432$, $P < 0.001$).

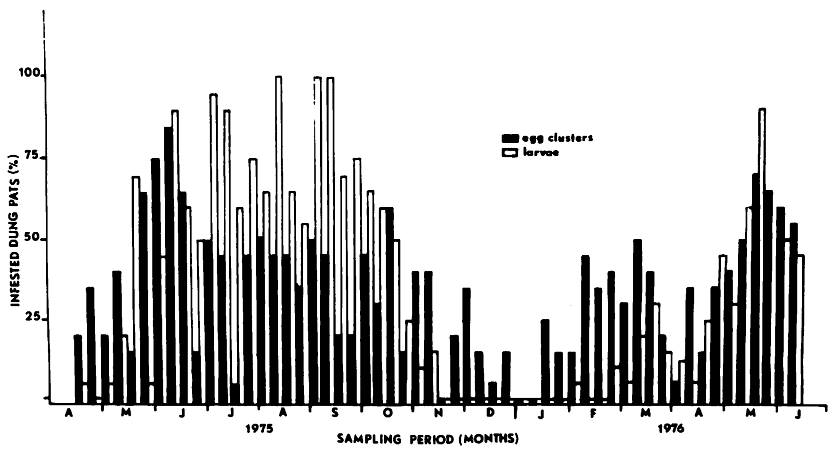

FIGURE 2. Seasonal variations in infestation rates of *M. sorbens* eggs and larvae in cow dung pats.

Dung pat fly populations—The number of larvae in dung pats during summer was significantly higher than winter (Fig. 3: $F_{1,43} = 17.687$, $P < 0.001$).

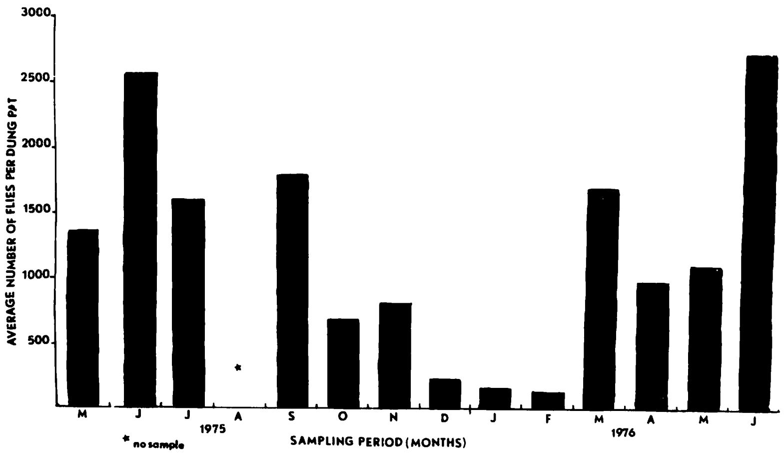

FIGURE 3. Seasonal variations in abundance of *M. sorbens* emerging from cow dung pats.

BIOLOGICAL CONTROL AGENTS

Predators—Arthropod fly predators caught in pitfall traps included the dermapateran, *Labidura riparia* (Pallas), the staphylinid, *Philonthus longicornis* Stephens, and the histerid beetles, *Atholus rothkirchi* Berkhardt, and *Saprinus fimbriatus* LeConte. The relative merits of these predators were studied by Toyama and Ikeda (1976).

The Common Mynah, *Acridotheres tristis tristis* (Linn.) was the only non-arthropod predator of *M. sorbens* observed in this study. Mynahs were observed feeding on *M. sorbens* egg clusters in dung pats throughout the day. Predation by these birds left characteristic shallow craters containing remnants of egg clusters in dung pats. Of 50 dung pats examined in a corral, 56% had an average of 2 egg clusters eaten by Mynahs.

Predation Rates—An 86.7% difference (Table 1) between the means of non-exposure and 5-day exposure samples observed during winter indicated that predation was the most probable cause of the low *M. sorbens* winter populations. A 40.5% difference (Table 1) between the means of 24 hour exposure samples observed during summer and winter also suggested that high summer breeding peaks were probably caused by a lack of predation on eggs and 1st instar larvae.

TABLE 1. *Seasonal Difference in Summer and Winter* **Parasitization Rate of** M. sorbens *Puparia*

Sampling Period	Viable Pupae (%)	Parasitized Pupae (%)	Dead* Pupae (%)	Total Sample
Summer	56.1	28.7	15.2	1958
Winter	44.7	43.6	11.7	2254

*Puparia failing to produce a parasite or fly.

Parasitization Rates: Higher parasitization rates occurred during winter months. However, 14.9% difference in rates was insufficient to be considered as the major cause of the low winter fly population. The hymenopteran pupal parasite *Spalangia endius* Walker accounted for almost all the parasitization occurring in both summer and winter.

Dung Pat Temperature: Ambient and dung pat temperatures (Fig. 4) diverged significantly during summer (ambient 29.16 ±0.80°C, dung pat 33.36 ±1.14°C). The significantly higher dung pat temperatures during summer demonstrated the effect of seasonal variation in sunlight intensity.

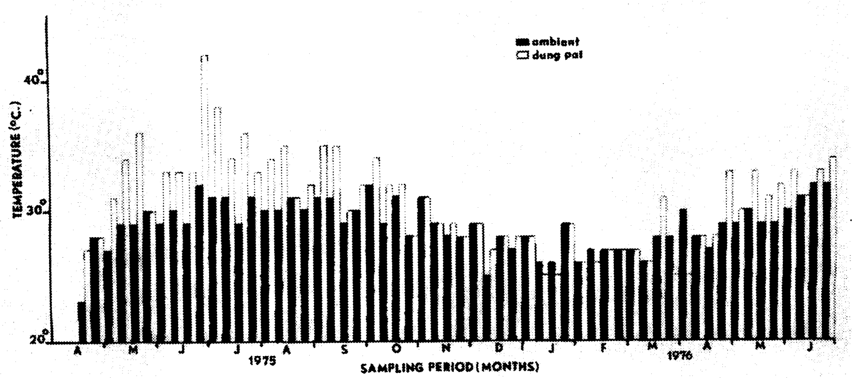

FIGURE 4. Seasonal differences between ambient and cow dung temperatures caused by 1/3 more intense summer solar radiation.

Meteorological Effects on Dung Pats: The only seasonal change observed in dung pats was the development of thick, hard crusts during the summer. Winter crusts were thin and became softened at night after reabsorbing moisture.

Dung Pat Crusts and Predation: *M. sorbens* populations in unsoftened dung pats were significantly higher ($F_{2,87} = 5.49$, $P < 0.001$) than in softened dung pats. This indicated that hard summer crusts were creating a physical barrier between predator and prey.

DISCUSSION

SEASONAL FLY ABUNDANCE

Except for March and April 1976 (Fig. 3) all data on seasonal abundance had similar population peaks usually beginning in May and ending in October. Increased egg deposition following the temporary suspension of oviposition during rainy periods in March and April was responsible for the increase of flies reared from dung pat samples.

BIOLOGICAL CONTROL AGENTS

Although we were unable to conclusively determine whether *L. riparia* was the major factor in causing seasonal abundance of *M. sorbens*, the data still indicated that biological control agents were responsible. Meteorological factors were discounted because surviving flies reared from winter dung pats exposed in the corral for 1-5 days developed normally and ranged in number from 4-3881 per pat. Detrimental changes in the dung pat environment from meteorological causes should have affected *M. sorbens* more uniformly. Seasonal variation in nutritional value of dung pats was also discounted as a factor since the ration formulation of gestating cows remained unchanged throughout the year.

Data indicating that biological control agents caused seasonal fluctuations in *M. sorbens* populations at the dairy were: (1) the 87.6% difference in *M. sorbens* populations found in field-exposed and unexposed dung pats during winter (Table 2); (2) the constant presence of dung pats with egg

TABLE 2. *Seasonal Difference in Predation Rates Upon* M. sorbens *Eggs and Larvae in Cow Dung Pats.* Mean ± S.E. (n = 30)

Sampling Period	No Exposure	24 Hours Exposure	3-5 Days Exposure
Winter	1667.26 ± 307.11 a/	753.53 ± 141 b/	206.46 ± 44.15
Summer	2494.56 ± 294.11	2173.16 ± 470.86	1654.36 ± 171.09

a/ Significantly different no-exposure and 24 hours exposure (t = 3.07 P = 0.01)

b/ 24 hours exposure significantly different summer and winter ($F_{5,174}$ = 16.06, P = 0.001)

clusters during winter without a corresponding number of pats containing larvae (Fig. 2); and (3) our observation of heavy infestations of *M. sorbens* after the insecticide, Phenothiazine, was incorporated into the feed of dry, gestating cows to control flies breeding in the animal's dung. During this period, we were able to capture 759 *M. sorbens* within 5 minutes in a cone trap. This high *M. sorbens* trap count, which occurred in the winter month of March 1973, never recurred (Fig. 1) after the use of Phenothiazane was discontinued. The decline of the *M. sorbens* population following the discontinuance of Phenothiazane in 1973 suggested that the biological control agents were accidentally eliminated by the insecticide while *M. sorbens* remained unaffected.

A. tristis tristis, *L. riparia*, and *S. endius* appeared to be the major biological control agents responsible for the low *M. sorbens* population during the winter months. Of these three, *L. riparia* was suspected as the predator most responsible for the seasonal abundance of *M. sorbens*. This conclusion was based on: (1) the observation that predation by the Mynah and parasitization by *S. endius* were unaffected by seasonal changes in the dung pat environment; (2) *L. riparia*, being the only nocturnal predator, was the most probable cause of the 54.8% overnight loss (Table 2) of *M. sorbens* in winter pats; and (3) *L. riparia* was the only predator observed engaging in nocturnal searching and predatory activity on dung pats in the field.

Ten pitfall traps caught an average of 2 adults and 5 immature *L. riparia* per trap during winter. Such a relatively small *L. riparia* population indicated that it was unlikely for this predator to exert such control over *M. sorbens* unless its primary prey were the eggs and undispersed clusters of newly hatched larvae. The potential of this predator was exhibited when 2 adult *L. riparia* in a petri dish were exposed to 8 large *M. sorbens* egg clusters containing several thousand eggs; only 192 2nd instasr larvae remained after 24 hours of exposure. Whether they were as effective in the field could not be determined.

Dung Pat Environment

Seasonal changes affecting predation were crust formation on dung pats and early hatching of fly eggs caused by a 1/3 more intense summer solar radiation (Atlas of Hawaii, 1973).Early hatching and subsequent dispersal and penetration of larvae into the dung before nightfall during summer probably caused increased survival from predation. However, the protective barrier afforded by the formation of impervious crusts during the summer was still considered to be the major cause of lower summer predation. This conclusion was based on data showing that summer pats with water-softened crusts had a 44.9% overnight loss of *M. sorbens* (Table 3) despite our observation that wetting of these crusts did not appreciably delay hatching of *M. sorbens* eggs before nightfall.

TABLE 3. *Populations of* M. sorbens *Remaining in Crusted and Uncrusted Cow Dung Pats after Exposure to Predators in the Field for 24 hours*

	Crusted Dung Pats (n = 30)	Uncrusted Dung Pats (n = 30)	Control Dung Pats (n = 30)
Flies per Pat	1772.83a/	976.63b/	1970.10

$F_{2,87} = 5.49$, $P < 0.01$

a/ Crusted dung pats significantly higher than uncrusted ($t = 2.88$ $P = 0.01$)

b/ Uncrusted dung pats significantly lower than control ($t = 2.94$ $P = 0.01$)

Summary

All data on seasonal fluctuation in the abundance of *M. sorbens* at a dairy on Kawailoa, Oahu showed similar population peaks that usually began in

May and ended in October. Seasonal abundance was apparently caused by the formation of hard crusts on dung pats during the summer that created a physical barrier between predator and prey. Summer crusting on dung pats was caused by a 1/3 more intense summer solar radiation.

Major biological control agents responsible for the low winter fly infestations were: (1) the Common Mynah, a bird that preyed on egg clusters; (2) *L. riparia*, an earwig that preyed on the eggs and larvae, and (3) *S. endius*, a hymenopteran fly pupal parasite. *L. riparia*'s inability to penetrate hard crusted dung pats during the summer to attack clusters of eggs and undispersed 1st instar larvae was suspected to be the primary cause of the summer fly abundance.

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